PARAMETER STUDY OF BOOST INVERTER TOPOLOGIES FOR HIGH VOLTAGE GAIN

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DEDICATION

In the name of Allah, the most Merciful, the most Compassionate, I dedicate this project to Allah ALMIGHTY, my source of knowledge and understanding.

I also dedicate this work to my beloved parents for their encouragement and continued support. To my dear brothers, sister, friends and beloved girl. Thank you all.

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ABSTRACT

To reducing electricity bills while reducing dependence on fossil fuels to generate electricity, the peoples use large amounts of solar energy. In addition to that, if the sunshine is available, that is the energy production depends on it, so that is beyond human control. The conventional Z-source network and switch inductor Z- source inverter is located between the DC voltage source and the inverter, which boosts the DC voltage. Traditional inverters such as voltage source inverters and current source inverters have few inherent limitations such as output voltage is limited to its input applied a voltage and usually, V-source inverters act like a buck converter, and likewise, I-source inverters operate as a boost converter. This two-stage configuration increases cost and reduces system efficiency. Also, the pass-through problem in the VSI and the open-circuit problem in the CSI are significant problems in system reliability. The structure proposed to overcome the above issues is a Z-source inverter (ZSI), which has a single-stage power conversion and a buck-boost voltage capability, unlike VSI and CSI inverters. On the other side, developing control technic is more complicated than that of the traditional inverters. For generating shoot through boost voltage, A DC envelope is introduced with the carrier signals to compare with it and make boost through zero state PWM signals, which have to be added with the traditional Modulated PWM, that are usually generated through comparison of the modulating sine wave with the carrier wave. In this research, the main objective is to designs a Z-source network circuit, SL Z-source inverter and embed with traditional single-phase H-bridge and to develop control logic, that would supply SPWM switching signals to IGBT gates. For this project, Simple constant boost control strategy has been developed and simulated in MATLAB / Simulink. For analysis, THD of the conventional Z-source inverter is 2.3% while THD for SL Z-source inverter is 1.44% and compare them see that the total harmonic distortion is better than traditional and also the boost factor and capacitor voltage stress are higher than conventional circuit when using same duty cycle and input voltage DC.

ABSTRAK

Untuk mengurangkan kebergantungan kepada bahan api dalam menjana tenaga eletrik, masyarakat menggunakan tenaga solar dalam jumlah yang banyak. Tambahan pula, jika terdapat cahaya matahari yang tersedia, penghasilan tenaga bergantung kepada kuasa tersebut, dan ia tidak dapat dikawal oleh manusia. Rangkaian Z-source dan suis pengaruh penyongsang Z-source terletak antara sumber voltan DC dan penyongsang yang meningkatkan voltan DC. Teknik graf aliran isyarat menganalisis rangkaian Z-source dengan prestasi yang ditingkatkan. Penyongsang tradisional seperti penyongsang punca voltan dan penyongsang punca arus terdapat limitasi inheren seperti pengurangan voltan keluaran berbanding input voltan gunaan dan selalunya, penyongsang V-source bertindak seperti penyongsang *buck*, dan pada masa yang sama, penyongsang I-source beroperasi sebagai penukar prestasi. Tatarajah dua tahap ini meningkatkan kos dan mengurangkan kecekapan sistem. Tambahan lagi, masalah *pass-through* di dalam VSI dan litar terbuka di dalam CSI adalah masalah yang nyata di dalam kebolehpercayaan sistem. Struktur yang dicadangkan untuk mengatasi isu di atas ialah penyongsang Z-source (ZSI), yang merangkumi satu tahap penukaran kuasa dan kebolehan peningkat *buck* voltan, tidak seperti penyongsang VSI dan CSI. Selain itu, mengembangkan teknik kawalan adalah rumit berbanding kawalan melalui penyongsang tradisional. Untuk menghasilkan peningkatan voltan, DC terselubung diperkenalkan bersama isyarat pembawa untuk dibandingkan dan meningkatkan isyarat PWM melalui keadaan sifar, yang perlu ditambah dengan PWM termodulat, yang selalunya dihasilkan melalui perbandingan dengan gelombang sine bersama gelombang pembawa. Melalui kajian ini, objektif utama adalah mereka bentuk rangkaian litar Z-source, penyongsang pembalik SL Z-source yang dibenamkan dengan H-bridge satu fasa yang tradisional dan menghasilkan logic kawalan, yang akan membekalkan signal pensuisan SPWM kepada *IGBT gates*. Untuk projek ini, strategi kawalan peningkan berkadar telah dihasilkan dan disimulasi di dalam MATLAB / Simulink. Untuk analisis, THD pada penyongsang lazim Z-source ialah

2.3% manakala THD untuk penyongsang SL Z-source ialah 1.44% dan telah dibandingkan untuk mengetahui bahawa herotan harmonik terseluruh adalah lebih baik berbanding tradisional dan peningkat faktor dan tegasan voltan kapasitor adalah lebih tinggi daripada litar konvensional apabila kitar tugas dan input voltan DC yang sama digunakan.

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LIST OF SYMBOLS AND ABBREVIATIONS

V	-	Volts
A	-	Ampere
PI	-	Proportional Integral
F	-	Farad
H	-	Henry
V_{DC}	-	Direct Current Voltage
V_{AC}	-	Alternating Current Voltage
V_{pk}	-	Peak Voltage
V_{pk-pk}	-	Peak to Peak Voltage
K_p	-	Proportional constant of PI controller
K_i	-	Integral constant of PI controller
PWM	-	Pulse Width Modulation
$SPWM$	-	Sine Pulse Width Modulation
$IGBT$	-	Insulated-gate Bipolar Transistor
K_C	-	Voltage ripple factor
K_L	-	Current ripple factor
M	-	Modulation index
B	-	Boost Factor
ZSI	-	Z-source inverter
$SL\ ZSI$	-	Switch Inductor Z-source inverter
ST	-	Shoot through
V_C	-	Capacitor voltage
V_l	-	Inductor voltage
V_{in}	-	Input DC voltage
V_{dc}	-	DC link voltage
D	-	Duty cycle

SBC	-	Simple boost controller
MBC	-	Maximum boost controller
CBC	-	Constant boost controller
THD	-	Total harmonic distortion
SCR	-	Silicon controllable rectifier
GTO	-	Gate-off thyristor
GaN	-	Gallium nitride

CHAPTER 1

INTRODUCTION

1.1 Background of study

The renewable energy sources are an alternative energy source. To reducing electricity bills while reducing dependence on fossil fuels to generate electricity, the peoples use large amounts of solar energy. Therewith, if the sunshine is available that is the energy production depends on it so that is beyond human control.

In the industry to convert DC voltages to AC voltages the traditional voltage source inverters (VSIs) are most utilized. The disability to boost voltage and cause damage to the converter when the legs of the switches are simultaneously turned on that is some main problems in VSI. So an inverter having an impedance network can be used for solving the mentioned issues. A conventional Z-source inverter (ZSI) includes one diode and two capacitors, two inductors. Z-source inverters are suitable for different applications, such as photovoltaic (PV) systems, to boost the voltage level and convert the DC voltage to AC. In [1], a photovoltaic system ZSI system appropriate for household loads has been proposed. In [2], ZSI increased the level of the output voltage and is also able to withstand short circuit conditions in the inverter branch known as the shoot through (ST).

A-source inverter is a relatively new design of DC to AC power converter, having the capability of step up or down the output voltage. It is mostly suitable in renewable energy applications such as solar panel MPPT control or wind turbine. Additionally, it is also fairly suitable for electric transport application. ZSI system comprises of three essential elements that are a DC input source, Z-source network and Inverter bridge. Using signal flow graph, boost performance of ZSI can be analyzed.

The impedance network of the Z-source inverter (ZSI) consists of separate inductors L_1 and $L_2$and capacitors $C_1$and C_2connected in an X-shape.

Inverters have been widely agreeable, demanding conversion from DC to AC. It can be in form of three phase or single phase H bridge network for wide range of low to high power applications in many consumer and industrial applications such as renewable energy, AC motors and even in house hold applications such as UPS and generators [4]. This unique impedance network has an extra zero state which is termed as non-shoot through zero state in addition of conventional six active and two non-active zero states. That additional ninth state enables the network to achieve boost or buck effect. Several algorithms have been proposed which are designed by modifying traditional PWM algorithm [5], [6].

Z source or impedance source inverter consist of a specially designed two capacitor and two inductor based impedance network in between H-bridge and input supply [2]. The above mentioned ninth zero switching state make the terminals of the inverter output short by simultaneously switching on either top and bottom switches. In that ST zero state, both inductors are charged through the stored energy of capacitors. Whereas in non-zero states, capacitors, combined with input source provide power to the load, similar to the working principle of boost converter.

While this unique impedance network based inverter have numerous advantages, but it also comes with few drawbacks. For instance, due to huge boost capability, high voltage stress is observed at capacitor and very large inrush current which results in distortion in output AC waveforms. For tackling these issues, integration of switched inductor SL technic is also proposed in ZSI network [7]. In this research a more advance SL network is proposed known as SL ZSI.

The SL Z-source inverter consists of four inductors (L_1, L_2, L_3, and L_4), two capacitors ($C_1$and C_2), and six diodes (D_1, D_2, D_3, D_4, D_5, and D_6).

1.2 Problem statement

In traditional voltage source and current source inverter, VSI and CSI respectively are having the capability of providing either single buck or single boost operation. For additional buck or boost in certain applications, extra conversion circuitry is required, which can increase the cost of the system and in addition effect on the system efficiency. Moreover, issues like pass through in VSI and open circuit in CSI can dramatically degrades the system effectiveness. In these scenarios, ZSI, which is a single stage unique impedance network can tackle these mentioned issues by providing either buck and boost features in that single stage circuitry.

Despite having many advantages, the ZSI has some problems such as the high total harmonic distortion and high voltage stress. For solve this problem must support another topology Z-source inverter that’s called SL Z-source inverter.

1.3 Objectives of the Study

(i) To improve Z-source inverter structure by introducing a switch inductor network for high voltage gain achievement and capacitor voltage stress.

(ii) To design an LC filter to improve total harmonic distortion voltage.

(iii) To develop PI control for the Z-source inverter for an output regulator.

1.4 Scope of the project

1. The system circuit will be developed by using MATLAB Simulink software.
2. DC voltage source will be used to emulate the changing of the PV system.
3. To obtain high voltage gain from the low voltage by using boosted Z-source inverter and SL Z-source inverter.
4. To obtain at the 240 (RMS) AC voltage pure sine wave.
5. Improve the voltage stress on the capacitors of the Z-network.

CHAPTER 2

LITERATURE REVIEW

2.1 Converter

In electrical engineering, power conversion can be termed as the conversion of electrical energy from one form to another. In [9], Power conversion systems typically include redundancy and voltage regulation. whether the input and output are alternating current (AC) or direct current (DC), can be classified a power conversion system is based on thus, DC-DC, AC-AC, DC-AC and AC-DC now characterize into DC-DC converter, voltage stabilizer and direct controller, second one is AC to DC group into rectifier, primary power supply (UPS) and switch mode power supply, third one is DC to AC inverter. Furthermore, AC to AC order into transformer, autotransformer, voltage converter, voltage controller, cycloconverter and variable recurrence transformer.

There are likewise varieties of devices and strategies for various power conversion applications intended for single and three-phase applications.

2.2 H-bridge single phase inverter

The power limit, simplicity of control and decreased expense of present day control semiconductor ICs enables more affordable manufacturing of converters in a wide scope and open up numerous typologies of power conversion in the field of power electronics. The inverter is a power conversion device that changes direct current flow (DC) into alternating current flow (AC).

The transformed AC current can be set to any voltage and frequency level by utilizing suitable switches like MOSFET and other control ICs. In [10] (Power Inverter) enables various high voltage electrical equipment such as computers, emergency power supply, uninterruptible power supplies (UPS) in in industrial and medical fields, various life support devices server farms, media communications, mechanical preparing, online administration frameworks, movable speed correspondence Drives, car applications, and AC hardware for homes.

At the point when utilized as an UPS, giving continuous, dependable and top notch quality of power from basic to critical needs. Moreover, power converters can be served as an extra stage of security to the important loads to avoid power blackouts such as overvoltage and overcurrent conditions.

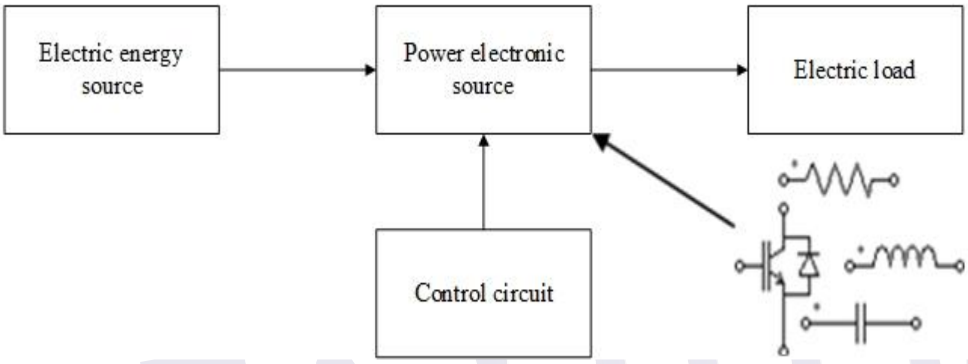

Figure 2.1: A fundamental Power Electronics System

The block diagram, illustrates in Figure 2.1, elaborates the power electronics stages [11]. Such as generation sources, necessary power circuits, control functions such as algorithms and software and electrical loads. Power electronic circuits include switches, storage components and step up and down transformers. The control engineer analyzes required information about the source, load, then designed required software and circuit design achieve the desired conversion process Controllers are normally constructed utilizing conventional low-power or digital equipment. For sinusoidal AC yield, the frequency, voltage and phase should be controlled properly. A standout amongst the most significant issues is the decision of selecting electronic circuit topology. For the best execution, it is important to consider the compatibility and specifications of power electronic components, since it is a power hardware innovation that power varieties of highly critical applications too.

Conventional DC/AC power converter is elaborated in Figure 2.2. It accepts DC power from input side (voltage or current) and the yield the output in terms of sinusoidal voltage [12]. Output can be any combinations of RLC, RC, RL or RE network or even AC voltage or current sink. Signals as a control parameter can be in terms of PWM, angle, phase voltage or current signals.

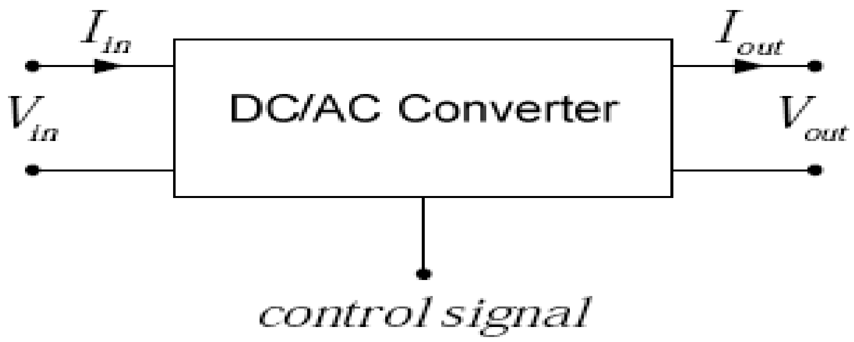

Figure 2.2: DC / AC converter Block [12]

The least complex type of the DC/AC converter is appeared in Figure 2.3(a) and is known as a single phase H-bridge. Single-stage DC/AC transformation can be achieved by opening and shutting the corner to corner switch sets, S1 and S4 or S2 and S3. Figure 2.3(b) demonstrates the yield voltage waveform where the yield voltage or negative yield voltage is seen at the output side, corresponding the switching states. According to [7] parameters of the AC voltage that is amplitude or RMS voltage should be consistent.

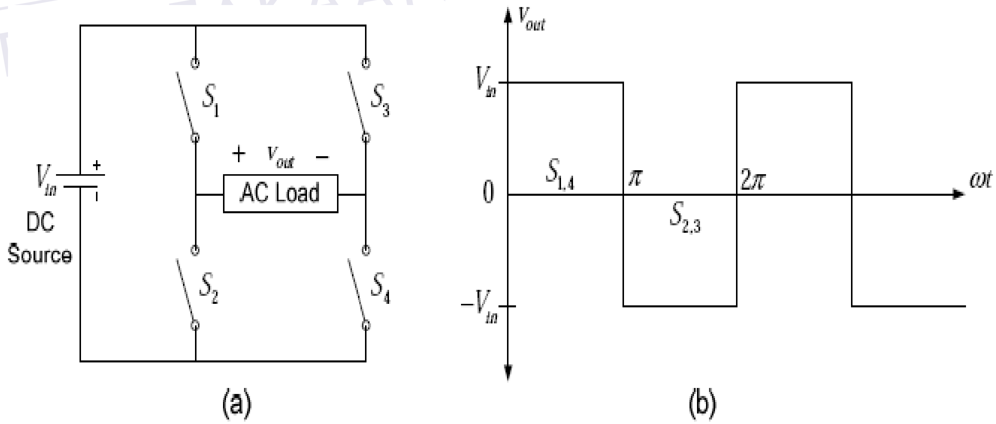

Figure 2.3: (a) Single phase bridge inverter (b) Waveform of the output AC voltage [12]

A common technique of adjusting the AC voltage parameters is to introduce a zero state. The zero states is obtained by turning off the switches S1 and S3 or the lower switches S2 and S4. Figure 2.4(a) illustrates the output AC voltage of the single-phase electrical converter of Figure 3(a). At the point when the zero states are utilized to change the AC voltage parameters. Various techniques for minimizing output harmonics are implemented by adding zero state. Heartbeat width regulation PWM or DAC strategies are likewise popular in DC/AC transformation. Utilizing high frequency switching algorithms, undesirable low frequency harmonics can be attenuated. In this way, high frequency components can be filtered with ease. Output waveforms of single phase inverter utilizing PWM technic is illustrated in Figure 2.4(a) and Figure 2.4(b). Here, switches S1 and S2 are enabled as high frequency switching, whereas switches S3 and S4 are enabled at low frequency. Afterwards, low frequency components of output voltage can be achieved through appropriate filtering.

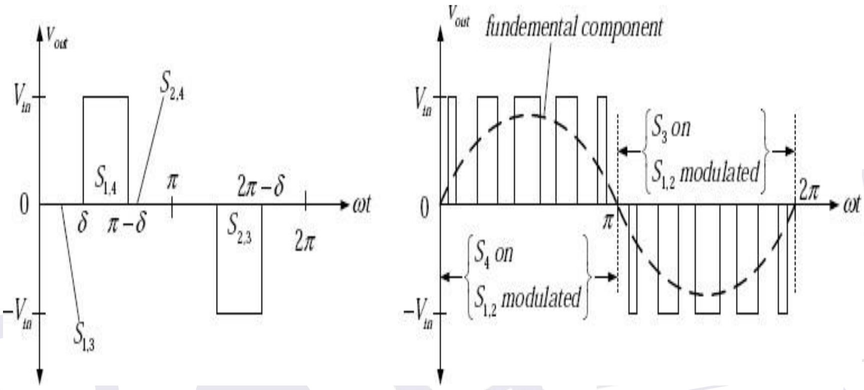

Figure 2.4: Output AC voltages (a) with zero state (b) with PWM control [12]

Figure 2.5 illustrates a typical voltage source inverter (VSI) and likewise. Figure 2.6 shows a conventional current source inverter (CSI). A regular VSI is a DC-AC buck inverter or AC-DC boost rectifier [13]. This implies the minimum AC voltage is restricted to input voltage and can't surpass the DC input voltage or in any condition, the DC voltage is greater than the AC input voltage. On the contrary, the typical CSI is a AC-DC buck rectifier or DC-AC boost inverter. The AC voltage yield is always more than the input DC voltage.

2.3 Problem and working principle of VSI

Figure 2.5 demonstrates conventional single phase voltage source converter termed as V source converter. A DC voltage source feeds with considerably large capacitor feeds the primary converter circuit, that is the H bridge circuit. Input voltage source can be a fuel cell stack, battery pack, a rectifier diode, and/ or a capacitor. Four switches are utilized in the fundamental circuit [14] each comprises of a power switch transistor and a freewheeling diode to give bidirectional current and unidirectional voltage blocking ability. On the other hand, it has few theoretical and practical restrictions.

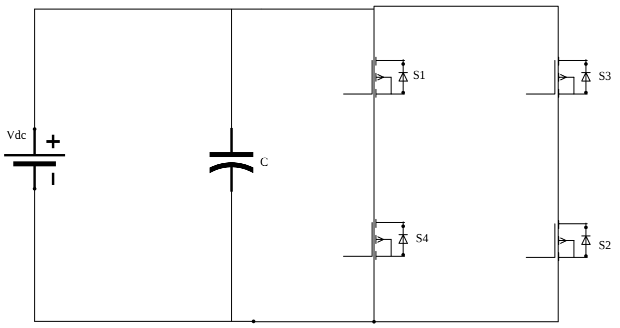

Figure 2.5: Traditional Voltage Source Inverter

The output AC voltage is constrained to lower limit of input voltage and can't surpass the DC voltage, [15] or the DC voltage must be more than the AC input voltage. Along these lines, the voltage source inverter is a (buck) inverter for DC-AC transformation, and a boost converter for AC-DC power conversion. For applications that require overdrive and restricted DC voltage accessible, an extra DC-DC boost converter can be added to accomplish the desired output yield. Extra stages of power converters increment cost dramatically and lower the system efficiency.

The upper and lower switches of the inverter bridge should not be turn on simultaneously by purpose or EMI noise. Else, short circuit occurs and the circuit will be damaged. The breakdown issue brought by electromagnetic interference (EMI) noise is the primary reason of inverter damage. The dead time of the upper and lower switches must be restricted in the voltage source converter, which can cause waveform distortion and so forth.

An LC filter is required to attain sinusoidal output waveforms. In comparison to CSI, it results in extra power loss and complex control.

2.4 Problem and working principle of CSI

Figure 2.6 demonstrates the structure of a conventional single-stage current source converter (condensed as an I-source converter). The DC power supply is the principle converter circuit, ie a single phase H bridge. The DC current source can be a moderately huge inductor controlled by a voltage source, for example, a battery, fuel stack, diode rectifier or thyristor switch. [10] Four switches are utilized in the principle circuit, each comprises of a semiconductor switches with reverse blocking capacity, for example, a controllable rectifier (SCR), a gate off thyristor (GTO) or a power transistor switch with a diode in series to enable the circuit to provide unidirectional current and bidirectional voltage blocking.

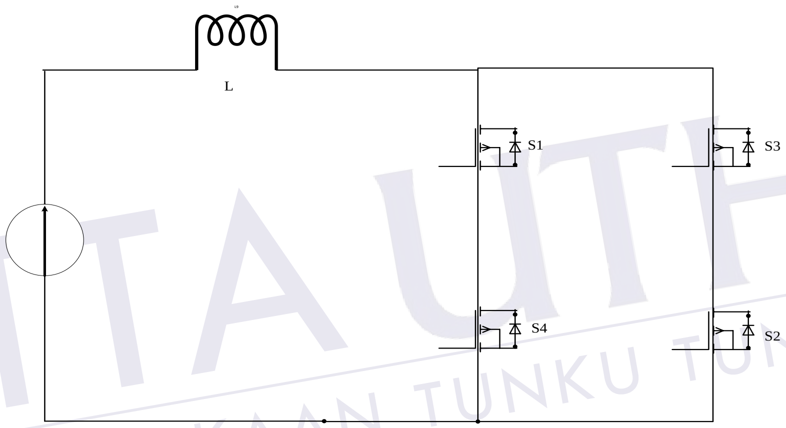

Figure 2.6: Traditional Current Source Inverter

Nonetheless, current source converters have the accompanying calculated and hypothetical obstacles and impediments.

The AC output voltage must be more noteworthy than the input DC voltage provided to the DC inductor. Else, the DC voltage created will be not exactly or less the AC input voltage. Consequently, the CSI is a boost inverter for DC-AC conversion, and a buck rectifier for AC-DC conversion. For applications require a wide voltage range of output, an extra DC-DC buck or boost converter is required. Extra power change stages increment effective cost and decrease productivity.

At least, anyone of the upper and lower switches must be gated on and kept up whenever. Otherwise, an open circuit condition of DC inductor will occur and the device will be harmed. The open circuit issue of EMI noise deluding is a noteworthy

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